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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 403 438 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
**31.03.2004 Bulletin 2004/14**

(51) Int Cl.7: **E02F 9/22**, E02F 3/38, F15B 21/08

(21) Application number: **03255946.0**

(22) Date of filing: **23.09.2003**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LI LU MC NL PT RO SE SI SK TR**
Designated Extension States:
**AL LT LV MK**

(30) Priority: **25.09.2002 US 255033**

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(54) **Method for preventing bounce oscillations of inertial masses caused by accelerations in hydraulically powered equipment**

(57) When a swinging boom (15) driven by a hydraulic cylinder (19) stops, inertia causes continued motion of the boom which increases pressure in a chamber (40,42) of the hydraulic cylinder. Eventually that pressure reaches a level which causes the boom to reverse direction. Then pressure in an opposite cylinder chamber (42,40) increases until reaching a level that causes the boom movement to reverse again.
This oscillation continues until the motion is dampened by other forces acting on the boom. As a result, an operator has difficulty in properly positioning the boom. To reduce this oscillating effect, a sensor (48,49) detects when the cylinder chamber pressure increases above a given magnitude and then a determination is made when the rate of change of that pressure is less than a defined threshold. Upon that occurrence, a control value (33,34) is opened to relieve the pressure in that cylinder chamber (42,40).

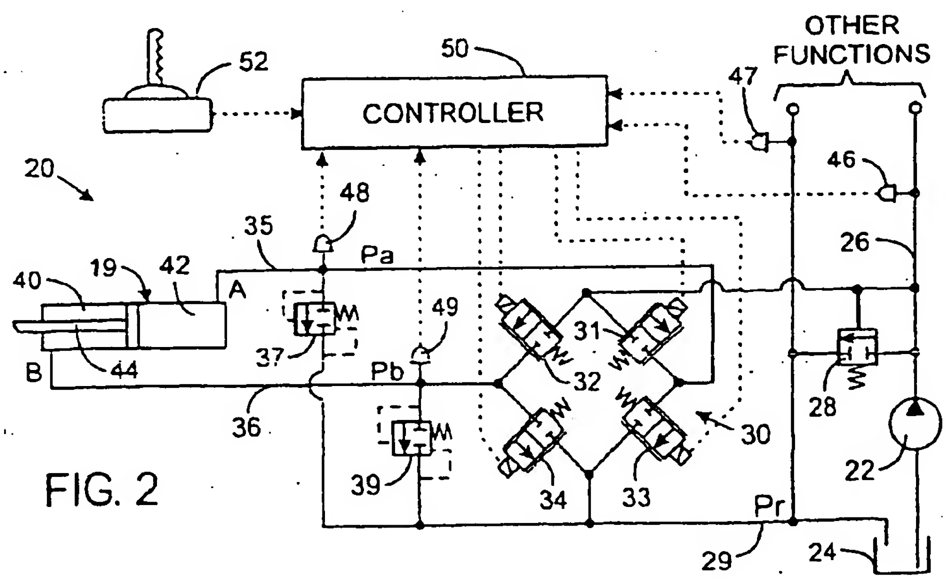



FIG. 2

EP 1 403 438 A1

## Description

### Background of the Invention

1. Field of the Invention

**[0001]** The present invention relates to hydraulically powered equipment, such as off-road construction and agricultural vehicles, and more particularly to apparatus for reducing bounce when a hydraulically driven member on the equipment is stopped suddenly.

2. Description of the Related Art

**[0002]** With reference to Figure 1, a backhoe 10 is a common type of earth moving equipment that has a bucket 12 attached to the end of an arm 14 which in turn is coupled by a boom 15 to the frame of a tractor 18. A joint 16 enables the bucket, arm, and boom assembly 17 to pivot left and right with respect to the rear end of the tractor. A hydraulic cylinder 19 is attached on one side of the tractor 18 to the boom 15 and provides the drive force for the pivoting motion. For larger backhoes, a pair of hydraulic cylinders are attached on opposite sides of the tractor 18 to pivot the boom. Hydraulic fluid is supplied to the cylinder 19 through valves that are manipulated by the backhoe operator. This movement of the boom 15 is referred to as "swing" or "slew".

**[0003]** As the boom swings, pressurized fluid is introduced into one chamber of the cylinder 19, referred to as the "driving chamber", and fluid is exhausted from the other cylinder chamber, referred to as the "exhausting chamber". When the operator suddenly stops the boom swing, inertia causes the motion of the backhoe assembly 17 to continue in the direction of the swing. The amount of inertia is a function of the mass of the backhoe assembly 17 and any material carried in the bucket 12. This continued movement after the control valves have been shut compresses the hydraulic fluid in the previous exhausting chamber of the cylinder 19 and may produce a void, or cavitation, in the previous driving cylinder chamber. Anti cavitation valves typically are provided in the hydraulic system to overcome this latter problem.

**[0004]** Eventually the backhoe assembly 17 stops and starts moving in the opposite swing direction due to the relatively high pressure created in the previous exhausting chamber. This subsequent movement produces a reversal of the pressure conditions, wherein the previous driving chamber of the boom swing cylinder 19 becomes pressurized. As a result, the backhoe assembly 17 swing oscillates until inherent dampening provided by other forces eventually brings the assembly to a stop. This phenomenon is known either as "swing bounce" or "swing wag" and increases the time required to properly position the boom 15, thereby adversely affecting equipment productivity.

**[0005]** Various approaches have been utilized to minimize the swing bounce. For example, U.S. Patent No. 4,757,685 employs a separate relief valve for each hydraulic line connected to the swing cylinder, which valves vent fluid to a tank line when excessive pressure occurs in that cylinder. Additional fluid is supplied from the supply line through makeup valves to minimize voids in the cylinder as the swing stops.

**[0006]** U.S. Patent No. 5,025,626 describes a cushioned swing circuit which also has relief and make-up valves connected to the hydraulic lines for the boom swing cylinder. This circuit also incorporates a cushion valve which in an open position provides a fluid path between the cylinder hydraulic lines. That path includes a flow restriction orifice. The cushion valve is resiliently biased into the shut position by a spring and a mechanism opens the cushion valve for a predetermined time period when the pressure differential between the cylinder chambers exceeds a given threshold.

**[0007]** Both of the previous circuits required a number of relatively complex valves. Therefore, it is desirable to provide a more simplified mechanism for reducing swing bounce.

### Summary of the Invention

**[0008]** A hydraulic system includes a control valve assembly, which selectively couples a pump and a tank to a hydraulic actuator that drives a member on a machine. The system has a device which produces a command designating desired movement of the load. A sensor detects pressure in the hydraulic actuator.

**[0009]** A method is provided to reduce bounce of the member when it stops. A command is received from the device designating that movement of the member in a given direction is to stop. The signal from the sensor is employed to determine the rate at which the pressure in the hydraulic actuator changes. When the rate of change of the pressure is less than a defmed threshold after receiving the command, pressure in the hydraulic actuator is relieved. For example the pressure is relieved by opening a control valve that is connected to the hydraulic actuator.

**[0010]** In one application, the present bounce reduction method is used on a machine in which the member is driven by a cylinder that has first and second chambers. It is a well-known practice that this type of installation includes first and second pressure relief valves that are respectively connected to the first and second cylinder chambers. Thus upon receiving the command, pressure in the second chamber is relieved by opening an associated control valve. Then a determination is made whether the first pressure relief valve is open due to excessive pressure in the first chamber. If the first pressure relief valve is found to be open, the bounce reduction method waits for that valve to close, and thereafter opens another control valve that relieves pressure remaining in the first chamber. Otherwise if the first pressure relief valve is found to be closed, the rate of pres-

sure change in the first chamber is determined, and pressure in the first chamber is relieved by opening the other control valve when the rate of pressure change is less than a defined threshold.

## Brief Description of the Drawings

**[0011]**

FIGURE 1 is a side view of a backhoe incorporating the present invention;

FIGURE 2 is a schematic diagram of a hydraulic circuit for the swing function of the backhoe boom;

FIGURE 3 is a block diagram of the microcomputer controller in Figure 2;

FIGURE 4 is a state diagram depicting operation of a swing bounce reduction routine that is executed by the controller;

FIGURE 5A graphically depicts pressure changes in a chamber of the hydraulic cylinder that swings the backhoe assembly; and

FIGURE 5B is a graph of the slope of the changing pressure in Figure 5A.

## Detailed Description of the Invention

**[0012]** With reference to Figure 2, a hydraulic circuit 20 for the backhoe 10 has a pump 22 which forces fluid from a tank 24 into a supply line 26. A conventional system pressure relief valve 28 opens in the event that the pump pressure exceeds a given safety threshold, thereby relieving that pressurized fluid to the tank 24 via the tank return line 29.

**[0013]** The supply line 26 and tank return line 29 are connected to a plurality of functions on the backhoe tractor 10. The hydraulic circuit for the boom swing function is shown in detail in Figure 2. A valve assembly 30 of four solenoid operated, directional control valves 31-34 selectively couples the supply line 26 and tank return line 29 to a pair of actuator conduits 35 and 36 which lead to ports of a hydraulic actuator, such as a cylinder 19, that swings the boom 15. Specifically, the supply line 26 is connected by the first directional control valve 31 to the first actuator conduit 35 and by the second directional control valve 32 to the second actuator conduit 36. The tank return line 29 is coupled by the third directional control valve 33 to the first actuator conduit 35 and by the fourth directional control valve 34 to the second actuator conduit 36. For example, the valve described in U.S. Patent No. 6,328,275 may be used in valve assembly 30. However, other types of valves may be utilized to implement the present inventive concept. The four directional control valves 31-34 are illustrated in the closed, or shut, position in which the actuator conduits 35 and 36 are disconnected from the pump and tank return lines 26 and 29. The first and second actuator conduits 35 and 36 also are designated by the letters A and B, respectively and the pressures in the actuator conduits (and the associated cylinder chamber) are designated Pa and Pb.

**[0014]** In the exemplary hydraulic circuit 20, the first actuator conduit 35 is connected to the head chamber 42 of the boom cylinder 19 and the second actuator conduit 36 is connected to the cylinder's rod chamber 40 which is a first chamber of the cylinder (19). Depending upon which specific ones of the four directional control valves 31-34 are activated, hydraulic fluid from the pump 22 is sent to one of the actuator conduits 35 or 36 and the other actuator conduit 36 or 35 is connected to the tank return line 29. Thus by opening either a combination of the first and fourth directional control valve 31 and 34 or the second and third directional control valves 32 and 33, the cylinder 19 is driven to extend or retract its piston rod 44 and thus move the backhoe boom 15 right or left. Although the present invention is being described in terms of operating a hydraulic cylinder, it should be understood that the novel concepts can be used with other types of hydraulic actuators, such as a hydraulic motor with a rotating shaft.

**[0015]** A first pressure relief valve 37 is connected to the first actuator conduit 35 to relieve excessive high pressure that may occur in the head chamber 42 which is a second chamber of the cylinder (19). Similarly, a second pressure relief valve 39 is connected to the second actuator conduit 36. These pressure relief valves 37 and 39 have a conventional design and are set to open at a significantly high pressure threshold. However, if a very heavy load is being carried in the bucket 12 when the boom 15 stops swinging, the pressure in a cylinder chamber due to the inertial load may exceed that threshold causing the associated pressure relief valve to open, as will be described. A pressure relief valve 37 or 39 opens when the pressure Pa or Pb in the respective actuator conduit 35 or 36 exceeds the pressure in the return line 29 plus a relief threshold, determined by force from a valve spring.

**[0016]** Pressure sensors are provided throughout the hydraulic circuit 20. Specifically, a first sensor 46 measures pressure in the supply line 26 and a second sensor 47 is located in the tank return line 29. Third and fourth pressure sensors 48 and 49 are provided in the first and second actuator conduits 35 and 36, respectively, and produce electrical signals indicating the pressure within the cylinder chambers 42 and 40 to which those actuator conduits are connected. The electrical signals from the four pressure sensors 46-49 are applied to inputs of an electronic controller 50. The controller 50 also receives input signals from an operator input device, such as a joystick 52. As will be described, the controller 50 responds to these input signals by producing output signals which activate the solenoids of the four directional

control valves 31-34 to operate the swing function of the backhoe assembly 17.

[0017] Referring to Figure 3, the controller 50 incorporates a microcomputer 54 which is connected by a set of buses 55 to a memory 56 in which the programs and data for execution by the microcomputer are stored. The set of buses 55 also connect input circuits 57 and output circuits 58 to the microcomputer 54. Each input circuit 57 for the pressure sensors 46-49 includes a first order, low-pass filter which attenuates frequencies above 100 Hz. This filtering removes any noise that might be present on the pressure sensor signals applied to the controller 50. The output circuits 58 provide signals to devices that indicate the status of the hydraulic system 20 to the backhoe operator. A set of valve drivers 59 controls the application of electricity to the solenoid coils in the four directional control valves 31-34. As will be described, the controller 50 executes software which implements a control algorithm for swinging the backhoe boom 15.

[0018] When the backhoe operator activates the joystick 52 to swing the boom 15 to the right or left, the signal generated by the joystick causes the controller 50 to begin executing a boom swing software routine that is stored in the memory 56. This routine controls selected ones of the four directional control valves 31-34 necessary to produce the indicated movement of the boom. On each execution pass through the control software for the backhoe 10, another routine is executed which detects when the boom swing is stopping and takes action to counter any significant bounce that may occur.

[0019] With reference to Figure 2 and the state diagram of Figure 4, the swing bounce reduction routine 60 commences at State 62 at which the routine remains when the boom is not swinging. In this State 62, the controller periodically tests to determine whether the boom is moving and if so, in which direction. To do so, the controller 50 examines the velocity command produced from the joystick signal. In the exemplary hydraulic system 20, a velocity command that is greater than zero indicates that the piston rod 44 is being extended from the cylinder 19, whereas a negative velocity command indicates that the piston rod is retracting into the cylinder. Assume initially that the velocity command is greater than zero, in which case a transition occurs from the Direction Test State 62 to the Swing Commanded State 64.

[0020] The operation of the swing bounce reduction routine 60 remains in this swing commanded State 64 until the operator manipulates the joystick 52 to indicate the boom is either stop or move in the opposite direction. That indication from the operator produces a new velocity command from the joystick which is either zero or a negative value in this situation. That change in the velocity command is detected at State 64 and produces a transition to State 66. If the velocity command now is zero, the routine for controlling the valve assembly 30 will close all four directional control valves 31-34.

[0021] The valve closure causes pressure within the rod chamber 40, from which fluid was previously being exhausted, to build up as the rod continues to extend from the cylinder due to the inertia load of the backhoe assembly 17. In addition, a significant pressure remains momentarily in the head chamber 42, which aids continued extension of the piston rod 44. Therefore upon entry into State 66, the swing bounce reduction routine 60 causes the third directional control valve 33 to open so that the pressure is relieved from the head chamber 42 to the tank return line 29. This initial pressure relief ensures that the pressure within the head chamber does not contribute to the continued motion of the backhoe assembly 17.

[0022] While the swing bounce reduction routine 60 is in State 66, the controller 50 periodically compares the absolute value of the velocity command to a velocity threshold. When the velocity command exceeds that threshold, the operator is again commanding motion of the backhoe assembly 17 in either direction. In that case, boom swing bounce is not a concern and a transition is made back to the Direction Test State 62 where the direction of the operator commanded boom motion is determined. This transition to State 62 also occurs when the operation remains in State 66 for more than 500 milliseconds. After remaining in State 66 for 180 milliseconds, the controller 50 Begins comparing the pressure level Pb in the rod chamber 40 to a first threshold level (THRESHOLD1) to determine whether the pressure within the previous exhausting cylinder chamber has build up to a significant level indicating that a bounce is likely to occur when the boom motion stops. The 180 millisecond delay prevents a pressure aberrations, which can occur momentarily when a directional control valve closes, from producing a state transition. Therefore, after the 180 milliseconds delay, if the pressure Pb within the rod chamber 40 exceeds the first pressure threshold a transition occurs to State 68.

[0023] At State 68 the controller 50 determines when to initiate a pressure relief operation to prevent rebounding of the backhoe assembly 17. In order to understand how the present swing bounce reduction routine 60 make that determination, reference is made to Figure 5A which graphically depicts pressure change within the rod chamber 40 following closure of the valves when the piston rod 44 is being extended. Initially that pressure rises until the motion of the boom 15 stops at time T1, after which the pressure Pb decreases as the boom moves in the opposite direction. The swing bounce reduction routine 60 makes one of two transitions from State 68 depending on whether the pressure rises to a level that causes the second pressure relief valve 39 to open. That event is indicated by pressure Pb in the second actuator conduit 36 exceeding the valve's constant relief threshold plus the pressure Pr in the return line 29, as represented by the input signal from sensor 47.

[0024] While the second pressure relief valve 39 re-

mains closed, the swing bounce reduction routine 60 at State 68 uses the rate of change of the pressure Pb to determine when to open the fourth direction control valve 34 to relieve that pressure and prevent rebound of the backhoe assembly 17. If that control valve is opened too soon, sufficient pressure will not build up in the rod chamber 40 to significantly slow the piston rod 44 and the attached backhoe assembly 17. In that situation, inertia may cause the boom assembly 17 to continue swinging until striking a stop at one end of the pivot joint 16. Conversely, if the valve is not opened soon enough, the pressure will not be relieved in time to prevent rebound of the piston and bounce of the backhoe assembly 17. The rate of change of the pressure Pb in the second actuator conduit 36 is employed as an indicator of when the backhoe assembly 17 has slowed enough that the pressure can be relieved in time to prevent boom bounce. The rate of change corresponds to the slope of the pressure curve in Figure 5A and is given mathematically by the derivative of the pressure which is plotted on the graph of Figure 5B.

[0025] Thus, the controller 50 employs the input signal from pressure sensor 49 at State 68 to determine the derivative (dPb/dt) of the pressure Pb in the second actuator conduit 36. The derivative value is checked to determine whether it is less than a second threshold (THRESHOLD2), indicated by a dotted line, which occurs as the rate of pressure change decreases just prior to the point 67 of maximum pressure. This condition indicates that the hydraulic actuator and the boom assembly attached thereto have slowed a given amount. When this condition exists while the second pressure relief valve 39 is closed (i.e. pressure Pb is less than the relief threshold plus the return line pressure Pr), a transition is made from State 68 to State 70.

[0026] The preferred embodiment of the swing bounce reduction routine 60 employs the rate of pressure change to determine when the hydraulic actuator and the boom assembly have slowed to a point at which action to reduce bounce can be taken. However, other methods for making that determination can be used instead, For example, a sensor can provide a signal indicating the swing position of the boom and the rate of position change used to determine when to implement bounce reduction. A velocity sensor or an accelerometer alternatively could be employed to detect when motion of the hydraulic actuator or the boom assembly has slowed to the point at which bounce reduction can be implemented.

[0027] At State 70, the controller 50 opens the fourth directional control valve 34 to relieve the pressure in the rod chamber 40 of cylinder 19 to the tank 24 via the return line 29. This prevents the pressure which has previously built up by the continued extension of the piston rod 44 from causing the piston rod to bounce back in the opposite direction. The fourth directional control valve 34 remains open for a fixed period of time (e.g. 40 milliseconds) after which the control valve is closed and a transition returns the swing bounce reduction routin the Direction Test State 62.

[0028] However, if a determination is made at Sta 68 that the second pressure relief valve 39 has openeo i.e. pressure Pb exceeds that valve's relief threshold plus the pressure Pr within the tank return line 29, a transition occurs to State 72. Because opening of the second pressure relief valve 39 provides a path which relieves pressure from the rod chamber 40, the swing bounce reduction routine 60 remains in State 72 until a closure of the second pressure relief valve 39 is detected. That closure is indicated by a the pressure Pb within the second actuator conduit 36 decreasing below the relief threshold plus the pressure in the tank return line 29, or by a pressure drop in the second actuator conduit 36 accompanied by a pressure increase in the first actuator conduit 35 as transpires when the piston rod 44 rebounds and moves in the opposite direction. When either of these conditions occurs, the swing bounce reduction routine 60 makes a transition from State 72 to State 74.

[0029] The controller 50 in State 74 opens the fourth directional control valve 34 to relieve any residual pressure within the rod chamber 40 for a predefined period (e.g. 30 milliseconds) after which the fourth directional control valve is closed. This action relieves the pressure within the cylinder 19 due to the inertial motion of the backhoe assembly 17 thereby preventing rebound of the piston and bounce of the backhoe boom 15. The swing bounce reduction routine 60 remains in State 74 for a total of 500 milliseconds after which a transition occurs back to the Direction Test State 62.

[0030] While in State 62, when the operator desires that the boom 15 swing in the opposite direction, as indicated by the joystick 52 producing a negative velocity command, a transition is made to State 76. State 76 is the reciprocal of State 74 and operation of the antibounce routine is similar thereto with the understanding that the boom 15 is moving in the opposite direction. Therefore, when the velocity command is zero or greater, as occurs when the operator intends to stop the boom or reverse its direction, another transition occurs to State 74. Because in this mode of operation the piston rod 44 is retracting into the cylinder 19, pressurized fluid from the pump 22 was previously applied to the rod chamber 40. Therefore at State 74, the fourth direction control valve is opened by the controller 50 to relieve that pressure Pb so that it does not contribute to the continued motion of the boom 15. Operation at this time is similar to that which occurred at State 66 when motion in the opposite direction was stopping. Therefore, under similar transition conditions, if the operator' movement of the joystick produces a new velocity command or 500 milliseconds have elapsed, a transition occurs back to the Direction Test State 62. Otherwise, the swing bounce reduction routine 60 eventually makes a transition to State 78.

[0031] In State 78, if the first pressure relief valve 37

is not detected as opened, the anti-bounce routine enters State 80 where the pressure in the head chamber is relieved by opening the third directional control valve 33. Thereafter, the operation returns to the Direction Test State 62. Otherwise, when the pressure Pa in the head chamber 42 is great enough to open the first pressure relief valve 37, a transition occurs to State 82 where the operation remains until the relief valve closure is detected. At that time, operation moves into State 66 where residual pressure within the head chamber 42 is relieved by opening the third direction control valve 33 for a predefined period before transitioning back to the Direction Test State 62.

[0032] The foregoing description was primarily directed to a preferred embodiment of the invention. Although some attention was given to various alternatives within the scope of the invention, it is anticipated that one skilled in the art will likely realize additional alternatives that are now apparent from disclosure of that embodiment. For example, although the invention has been described in the context of reducing swing bounce of a backhoe assembly, the novel technique can be applied to other types of motion by a variety of machine members. Accordingly, the scope of the invention should be determined from the following claims and not limited by the above description.

## Claims

1. A method for controlling movement of a member (15) that is driven by a hydraulic actuator (19) connected to a valve assembly (30) through which fluid flows, the method comprising:

   receiving a command designating that movement of the member in a given direction is to stop;
   in response to receiving the command operating the hydraulic actuator (19) to stop the movement of the member (15);
   sensing a parameter which varies with movement of the member;
   analyzing the parameter to determine when a predefined condition occurs as the movement of the member is stopping and in response thereto producing an indication; and
   in response to the indication and to receiving the command, relieving pressure in the hydraulic actuator (19).

2. The method as recited in claim 1 wherein analyzing the parameter determines when movement of the member (15) has slowed to a defined speed.

3. The method as recited in claim 1 wherein:

   sensing a parameter comprises sensing pressure occurring in the hydraulic actuator (19); and
   analyzing the parameter determines a rate at which the pressure changes and produces the indication when the rate is less than a defined threshold.

4. The method as recited in claim 1 wherein analyzing the parameter determines a rate at which the parameter changes and produces the indication when the rate has a defined value.

5. The method as recited in claim 1 wherein relieving pressure in the hydraulic actuator (19) comprises opening a control valve (33,34).

6. The method as recited in claim 1 wherein relieving pressure in the hydraulic actuator (19) is further in response to the pressure in the hydraulic actuator being greater than a threshold value.

7. The method as recited in claim 1 further comprising:

   determining whether a pressure relief valve connected to the hydraulic actuator (19) is closed; and

   wherein relieving pressure in the hydraulic actuator (19) occurs in response to the hydraulic actuator being closed.

8. The method as recited in claim 7 wherein determining whether the pressure relief valve (37,39) is closed is based on comparing pressure in the hydraulic actuator (19) to a defined pressure level.

9. The method as recited in claim 7 further comprising when the pressure relief valve (37,39) is determined not to be closed, opening a valve (33,34) in the valve assembly.

10. The method as recited in claim 1 further comprising:

    determining whether a pressure relief valve (37,39) connected to the hydraulic actuator (19) is open after receiving the command;
    after determining that the pressure relief valve (37,39) is open, detecting closure of the pressure relief valve; and
    upon detecting closure of the pressure relief valve (37,39), opening a control valve (33,34) that relieves pressure remaining in the hydraulic actuator (19).

11. The method as recited in claim 10 wherein detecting closure of the pressure relief valve (37,39) comprises detecting when pressure in the hydraulic actuator (19) decreases below a given level.

12. The method as recited in claim 1 wherein:

the hydraulic actuator (19) has a first chamber (40) and a second chamber (42);
sensing a parameter comprises sensing pressure in the first chamber, and determining a rate at which the pressure in the first chamber changes; and
analyzing the parameter comprises determining when the rate of change of the pressure is less than a defined threshold.

13. The method as recited in claim 12 wherein relieving pressure in the first chamber (40) occurs only after pressure in the first chamber exceeded a defined threshold.

14. The method as recited in claim 12 wherein relieving pressure comprises, for a given period of time, opening a control valve (34) connected to the first chamber.

15. The method as recited in claim 12 further comprising relieving pressure in the second chamber (42) in response to receiving the command.

16. The method as recited in claim 15 wherein relieving pressure in the second chamber (42) comprises opening a control valve (33) for a defmed period of time.

17. The method as recited in claim 1 further comprising:

determining whether a pressure relief valve (39) connected to the first chamber (40) is open or closed; and
after receiving the command:

(a) if the pressure relief valve (39) is open, determining when the pressure relief valve closes and thereafter relieving pressure remaining in a first chamber (40) of the hydraulic actuator (19), and
(b) if the pressure relief valve (39) is closed, determining a rate of change of the pressure in the first chamber (40), and relieving that pressure in response to the rate of change being less than a defmed threshold.

18. The method as recited in claim 17 further comprising relieving pressure in a second chamber (42) of the hydraulic actuator (19) in response to receiving the command.

19. The method as recited in claim 17 wherein determining whether the pressure relief valve (39) is open comprises determining whether the pressure in the first chamber (40) is greater than a given pressure level.

20. The method as recited in claim 17 wherein determining when the pressure relief valve (39) closes comprises detecting when pressure within the first chamber (40) decreases below a given pressure level.

21. The method as recited in claim 16 wherein determining when the pressure relief valve (39) closes comprises detecting when pressure in the first chamber (40) decreases and pressure increases in a second chamber (42) of the hydraulic actuator (19).

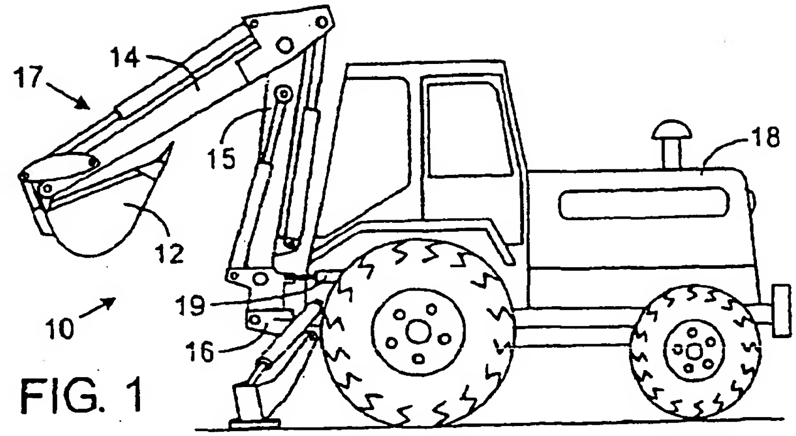



FIG. 1

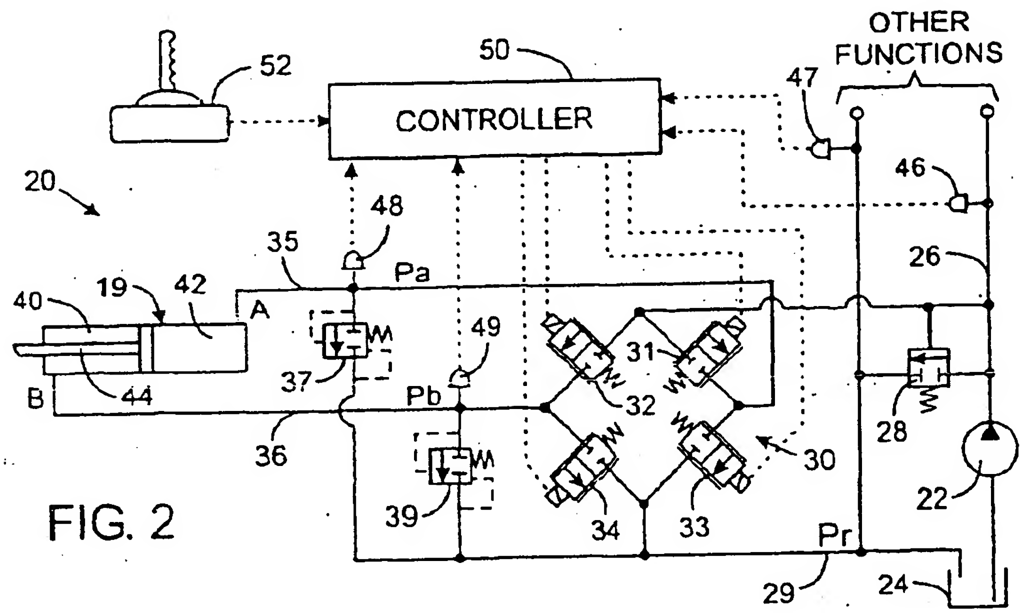



FIG. 2

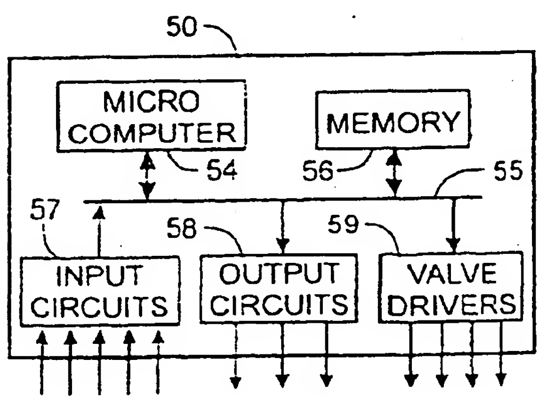



FIG. 3

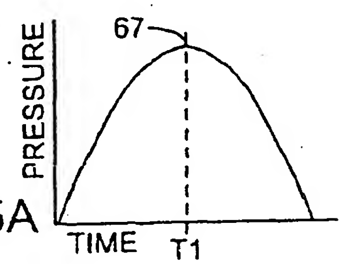



FIG. 5A

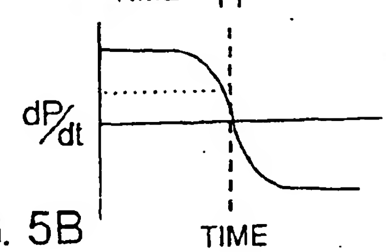
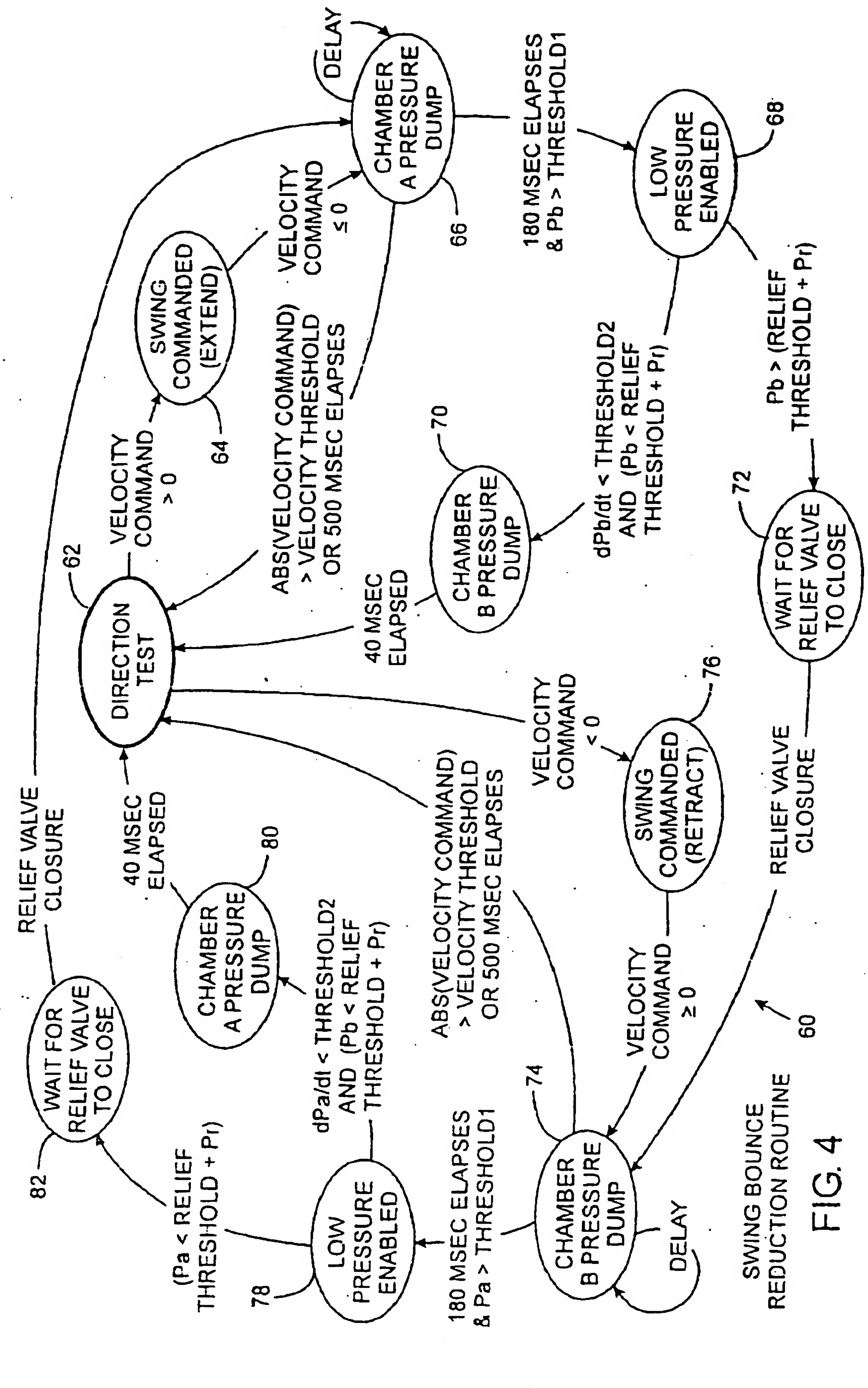



FIG. 5B



DIRECTION TEST
62
VELOCITY COMMAND > 0
SWING COMMANDED (EXTEND)
64
VELOCITY COMMAND
VELOCITY COMMAND ≤ 0
CHAMBER A PRESSURE DUMP
66
DELAY
ABS(VELOCITY COMMAND) > VELOCITY THRESHOLD OR 500 MSEC ELAPSES
180 MSEC ELAPSES & Pb > THRESHOLD1
LOW PRESSURE ENABLED
68
dPb/dt < THRESHOLD2 AND (Pb < RELIEF THRESHOLD + Pr)
CHAMBER B PRESSURE DUMP
70
40 MSEC ELAPSED
Pb > (RELIEF THRESHOLD + Pr)
WAIT FOR RELIEF VALVE TO CLOSE
72
RELIEF VALVE CLOSURE
VELOCITY COMMAND < 0
SWING COMMANDED (RETRACT)
76
VELOCITY COMMAND ≥ 0
ABS(VELOCITY COMMAND) > VELOCITY THRESHOLD OR 500 MSEC ELAPSES
CHAMBER B PRESSURE DUMP
74
DELAY
180 MSEC ELAPSES & Pa > THRESHOLD1
LOW PRESSURE ENABLED
78
dPa/dt < THRESHOLD2 AND (Pb < RELIEF THRESHOLD + Pr)
CHAMBER A PRESSURE DUMP
80
40 MSEC ELAPSED
(Pa < RELIEF THRESHOLD + Pr)
WAIT FOR RELIEF VALVE TO CLOSE
82
RELIEF VALVE CLOSURE
SWING BOUNCE REDUCTION ROUTINE
60


FIG. 4

European Patent Office

# EUROPEAN SEARCH REPORT

Application Number
EP 03 25 5946

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.7) |
|---|---|---|---|
| X<br>A | EP 0 378 129 A (HITACHI CONSTRUCTION MACHINERY) 18 July 1990 (1990-07-18)<br>* column 11, line 34 - column 12, line 20; figure 5 *<br>* column 13, line 52 - column 14, line 40; figures 7,8 *<br>* column 15, line 15 - column 17, line 24; figures 10,11 *<br>* column 19, line 1 - line 21; figures 21A,21B *<br>* column 20, line 16 - column 22, line 23; figures 16,17 * | 1,5,6<br>2-4,7-21 | E02F9/22<br>E02F3/38<br>F15B21/08 |
| X | PATENT ABSTRACTS OF JAPAN vol. 1995, no. 01, 28 February 1995 (1995-02-28) -& JP 06 280281 A (SUMITOMO CONSTR MACH CO LTD), 4 October 1994 (1994-10-04)<br>* abstract; figures * | 1,6 | |
| A | US 4 718 329 A (HONMA KAZUO ET AL) 12 January 1988 (1988-01-12)<br>* the whole document * | 1-21 | TECHNICAL FIELDS SEARCHED (Int.Cl.7)<br>E02F<br>F15B |
| A | DE 44 40 310 A (SAMSUNG HEAVY IND) 5 October 1995 (1995-10-05)<br>* the whole document * | | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| MUNICH | 9 January 2004 | Laurer, M |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number

EP 03 25 5946

## CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☒ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent Office

# LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 03 25 5946

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1+2-4,12-16,21

   directed to the method of claim 1 wherein the actuator speed, a pressure change rate, a parameter change rate or the pressure change rate in an actuator chamber is sensed for analysing whether a predefined condition is fulfilled;

2. Claim : 1+5

   directed to the method of claim 1 wherein pressure relief is effected by opening a control valve;

3. Claim : 1+6

   directed to the method of claim 1 wherein pressure relief is effected if the pressure in the actuator exceeds a threshold value;

4. Claims: 1+7-9

   directed to the method of claim 1 wherein the state of a pressure relief valve is determined as feedback signal;

5. Claims: 1+10-11

   directed to the method of claim 1 wherein the control valve and the relief valve are controlled in a combined manner;

6. Claims: 1+17-20

   directed to the method of claim 1 wherein method steps similar to the steps of claims 7 and 12 are combined;

# ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 03 25 5946

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

09-01-2004

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 0378129 A | 18-07-1990 | JP 2190532 A | 26-07-1990 |
| | | JP 2739225 B2 | 15-04-1998 |
| | | JP 2190533 A | 26-07-1990 |
| | | JP 2688967 B2 | 10-12-1997 |
| | | JP 2190534 A | 26-07-1990 |
| | | JP 2688968 B2 | 10-12-1997 |
| | | DE 69014312 D1 | 12-01-1995 |
| | | EP 0378129 A1 | 18-07-1990 |
| | | KR 9207652 B1 | 14-09-1992 |
| | | US 5048296 A | 17-09-1991 |
| JP 06280281 A | 04-10-1994 | NONE | |
| US 4718329 A | 12-01-1988 | JP 1811203 C | 27-12-1993 |
| | | JP 5014121 B | 24-02-1993 |
| | | JP 61180001 A | 12-08-1986 |
| | | JP 1811224 C | 27-12-1993 |
| | | JP 5014803 B | 26-02-1993 |
| | | JP 62052202 A | 06-03-1987 |
| | | JP 1811225 C | 27-12-1993 |
| | | JP 5014804 B | 26-02-1993 |
| | | JP 62052203 A | 06-03-1987 |
| | | DE 3660226 D1 | 30-06-1988 |
| | | EP 0190703 A1 | 13-08-1986 |
| DE 4440310 A | 05-10-1995 | KR 208734 B1 | 15-07-1999 |
| | | DE 4440310 A1 | 05-10-1995 |
| | | JP 8042507 A | 13-02-1996 |
| | | US 5510987 A | 23-04-1996 |



For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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